

DSS Baseline Performance Report
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A Gulf Coast Monitoring and Hazards Decision Support Tool – Enhancements Using NASA Earth Science Products, Data and Models

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This baseline performance report will provide a benchmark by which the DSS will be enhanced with NASA Earth science research results (e.g., satellite observations, scientific results, model outputs) and provide a measure of comparison to the application performance without the NASA results in the context of decision-making related to coastal management in the northern Gulf of Mexico. The enhanced DSS will focus on integrating NASA Earth science results into the WAVCIS decision support system that presently serves environmental resource and emergency management and response mainly for the Louisiana coastal region. NASA results and model outputs will be extended to a larger coastal region that will include the states of Mississippi and part of Texas coast and will be integrated with the WAVCIS DSS through a web-based portal (the Gulf Coast information System). The project will use the outputs of a coastal predictive model, and data/products from satellite observations such as MODIS Aqua/Terra, QuikSCAT, and Jason. The project will evaluate, verify, validate and benchmark these NASA measurements and work to extend and use the results with partners such as MMS and LDNR and other users.

1. Description of current DSS

The coastal U.S. region comprising of Louisiana, Mississippi and Texas have been particularly prone to land loss, flooding and have been impacted by natural disasters such as hurricanes. This deltaic region influenced by the Mississippi River system is also expected to experience the effects of enhanced sea level rise associated with global climate change. At the same time, natural resources in this coastal region is also one of the most highly developed and exploited, with oil and gas drilling/production, fisheries and offshore sand mining for coastal restoration.

In recent years, coastal Louisiana has been strongly impacted by hurricanes and storms and the region did not have any wave and storm surge monitoring capability. The operation of nearshore and offshore platform based coastal decision system such as the WAVCIS (Wave-Current-Information System) by the Coastal Studies Institute at Louisiana State University (LSU) has provided the capability for near real-time monitoring of oceanographic and meteorological parameters off the Louisiana coast. WAVCIS consists of instrumentation deployed on platforms that are located in deep and shallow waters off the Louisiana coast. Field data is transmitted from the platforms by solar-powered cellular links to a base station at LSU. Data at the base station undergoes quality control, post-processing and archiving in an online database. WAVCIS presently has 6 operational platforms (Figure 3; including one recently installed for DoD in Fort Walton, Florida). All the stations measure both oceanographic and meteorological parameters. Oceanographic parameters being measured/derived include wave information (significant wave height, maximum wave height, average wave period, peak wave period, dominant wave direction, current information (current speed and direction), sea level (tide) and sea surface temperature. Atmospheric parameters being monitored include wind speed and direction, air temperature, barometric pressure, air temperature and humidity. Processed information is posted on the World Wide Web and is accessible to computers with an Internet connection and web

browser. The field data is updated every hour. Remote sensing data from the GOES-12 Geostationary satellite is also provided to the WAVCIS system through a website link. Additional internet links have been made recently to the WAVCIS website to provide model forecasts of waves and currents. The Louisiana Office of Homeland Security and Emergency Preparedness, utilizes the information provided by WAVCIS in their decision making during the hurricane season.

Information provided by the WAVCIS system is also being used for other decision making by both Federal and State Agencies. WAVCIS field information (e.g., currents) is used to assist the Louisiana Oil Spill Coordinator's Office to monitor oil spill along the Louisiana coast, a region with one of the highest oil spill incidences in the country. The Minerals Management Service (MMS-Department of the Interior) has funded and uses the information provided by WAVCIS to monitor and evaluate sand mining effects in SW Louisiana for coastal restoration. Recently, MMS and the Louisiana Department of Natural Resources (LDNR) have funded two projects titled "Environmental investigations of the long-term use of Ship shoal sand resources for large-scale beach and coastal restoration in Louisiana" and "Environmental investigation of the long-term use of Trinity and Tiger shoals as sand resources for large-scale beach and coastal restoration in Louisiana". In addition, one WAVCIS platform located in the Mississippi River Bight has been populated with additional sensors to measure chlorophyll, turbidity, and dissolved oxygen to support hypoxia studies. WAVCIS however provides the information at limited field locations along the Louisiana coast. Integration of NASA products and model outputs (3-dimensional predictions of sea level, currents, temperature, and salinity) at higher and larger spatial resolution will help enhance management decisions using the enhanced WAVCIS DSS.

2. Outline of enhancements anticipated by the proposed work

In this project, we plan to enhance the current WAVCIS DSS with NASA satellite products and coastal circulation models and extend the DSS to a larger spatial region in the northern Gulf of Mexico to include Mississippi, Louisiana and the eastern part of Texas (Figure 1).

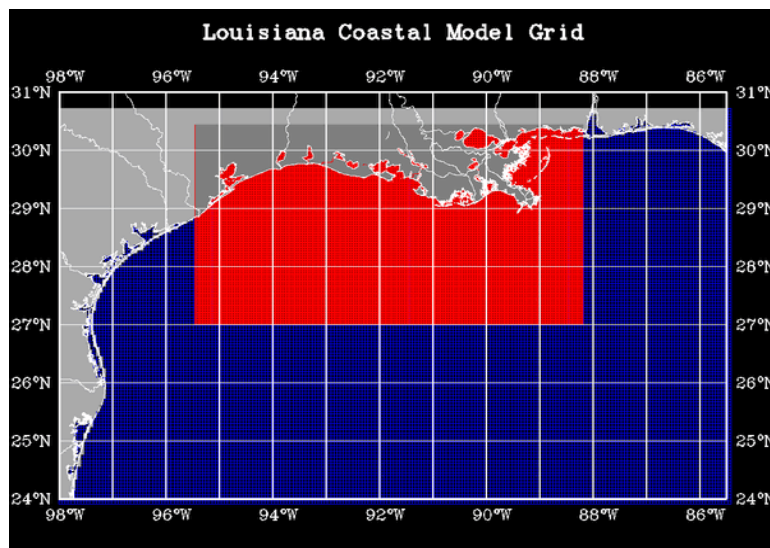


Figure 1. The spatial extent of the 3-D model outputs and NASA satellite results (red grid) that will be integrated into the WAVCIS DSS.

In addition, the model and NASA remote sensing results will be integrated into the DSS to include the Outer Continental Shelf (OCS) up to 27° N latitude, a region of interest to MMS where increasingly oil and natural gas exploration is taking place in deeper waters of the northern Gulf of Mexico. An overview of the integrated systems solution chart for the Gulf Coast Information System that will be used to enhance the WAVCIS DSS will include the coastal region of Mississippi, Louisiana and the eastern part of Texas and the outer continental shelf in the northern Gulf of Mexico (Figure 2).

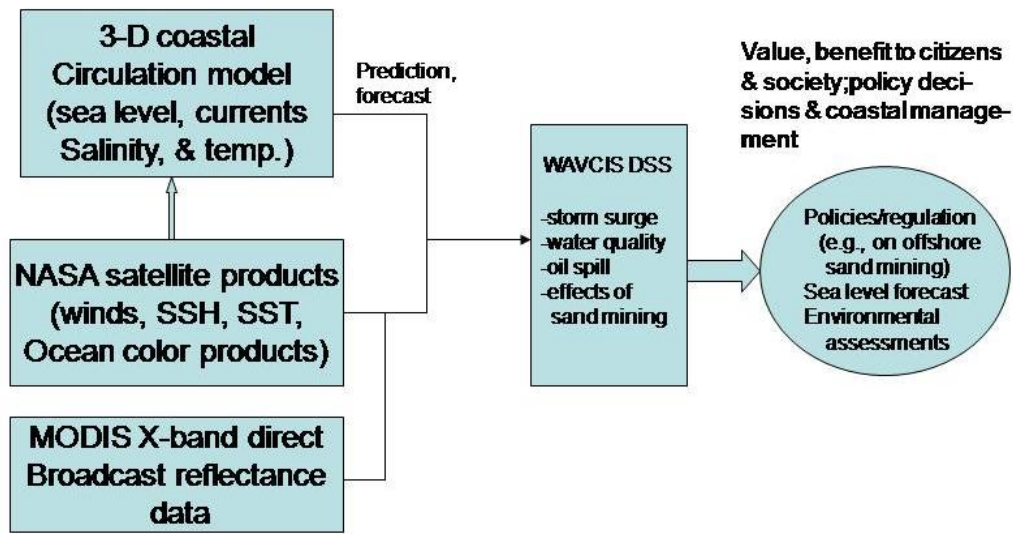


Figure 2. Integrated Systems Solution Chart for the enhanced WAVCIS DSS.

Satellite products and data that are planned to be integrated into the WAVCIS system includes wind data from SeaWinds/QuikSCAT at 25 km spatial resolution, sea surface height (SSH) from Jason-1, sea surface temperature (SST) and ocean color products from the MODIS sensor on Aqua satellite. Additional data products from Jason includes wind speed and wave heights, while a new wind speed product from the QuikSCAT sensor at 12.5 km spatial resolution is available from DAAC and will be integrated into the DSS.

Due to the limited spatial extent and number of WAVCIS stations, field data from NDBC buoys at various locations in the northern Gulf of Mexico will be incorporated into the enhanced DSS and its data used for validation of NASA products. Many of the NDBC buoys are located in the outer continental shelf region, and along the Texas and Mississippi coast, coastal regions with no operational WAVCIS platforms. Data being acquired by the NDBC buoys include hourly measurements of wind speed and direction, wave height/period and direction, and water temperature. In addition, atmospheric parameters such as air temperature, barometric pressure and dew point are measured. Data from the NDBC buoys in the Gulf are available on the NDBC website for download and will be integrated into the enhanced DSS. Data from the NDBC buoys will also be used for validation and verification of the satellite data such as winds and wave height products from QuikSCAT and Jason-1 (Figure 3).

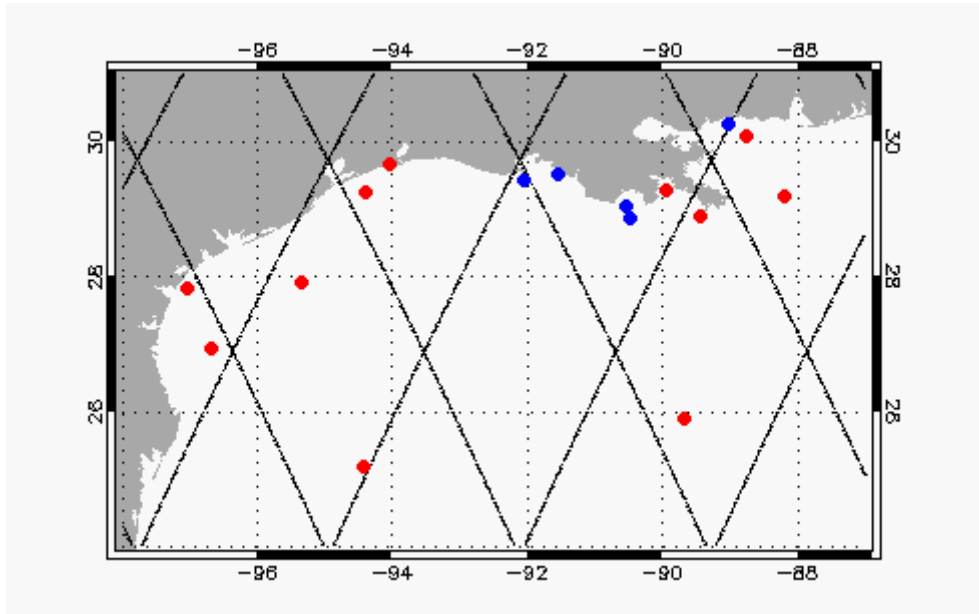


Figure 3. An example of Jason-1 tracks and location of NDBC buoys (red dots) and WAVCIS stations (blue dots) in the Gulf of Mexico that are planned to be used in V&V effort.

In addition to using the standard NASA results, the WAVCIS DSS will be supported by direct acquisition of satellite data from the MODIS X-band direct broadcast system (reflectance data) at LSU's Earth Scan Laboratory. NASA remote sensing data/observations are available as geophysical parameters that have been produced through efforts of the Science Teams with the goal to answer specific science questions about the Earth system processes. Due to the complexity of river-dominated coastal waters, some of the ocean color products such as Total Suspended Matter (TSM) and chlorophyll may require validation with field measurements since uncertainty still exists in the estimates of these standard NASA generated products in optically complex coastal waters. The PI has been acquiring field data and will also acquire additional field data during 2008 and 2009 field campaigns in the northern Gulf of Mexico as part of a separate MMS funded project to improve satellite estimates of water quality variables in the coastal and OCS region in the northern Gulf of Mexico. In addition to the standard NASA ocean color products, we plan to use regionally developed algorithms for chlorophyll and TSM to integrate and deliver to the DSS. Other standard ocean color products (absorption due to CDOM and detrital material) have also been developed by the NASA science teams and will be incorporated into the DSS. These products will support MMS Environmental Studies Program that uses environmental information to support decision-making concerning leasing and the use of offshore resources.

A real-time ocean nowcast/forecast system (ONFS) has been developed at the Naval Research Laboratory (NRL). The NRL ONFS is intended for producing a daily, short-term (under a week) forecast of mesoscale ocean current, temperature, salinity, and sea level variation including tides. The system is modularized so that each component, for example the ocean dynamic model, can be replaced. The system can be relocated to different locations and, once set up for a particular

region, operates automatically. The system is an integration of a data-assimilating, dynamical ocean model, a statistical data-analysis model, and various data streams for ocean bathymetry, climatological data, surface forcing, open boundary forcing, and observations for data assimilation. The NRL Modular Ocean Data Assimilation System (MODAS) is used within the ONFS as the data analysis model. MODAS uses satellite data, in-situ observations, and historical statistics to generate three-dimensional ocean temperature and salinity analyses. The analyses are then assimilated into the dynamic model to produce an ocean nowcast. From the nowcast, the forecast is conducted without data assimilation using a meteorological forecast.

The NRL real-time ONFS was first implemented for the North Pacific Ocean and was called the North Pacific Ocean Nowcast/Forecast System and operated in real-time from 1999 to 2004. The NPACNFS produced a nowcast and 72-hour forecast every 24 hours and the predictions were subjected to several evaluations and used for a number of studies. The ONFS was later implemented for several other regions including the Intra-Americas Sea (IASNFS), which covers the Gulf of Mexico, Caribbean Sea, and Straits of Florida. The real-time IASNFS nowcasts and forecasts are available at the web site: http://www7320.nrlssc.navy.mil/IASNFS_WWW/. The ocean model applied in the IASNFS is based on the Navy Coastal Ocean Model (NCOM). NCOM is similar to the Princeton Ocean Model (POM) but has options to use hybrid vertical coordinates and multiple nesting. In all these ONFS implementations, the real-time data for the data assimilation are from satellite altimeters and AVHRR. The surface forcing is either from the Navy Operational Global Atmospheric Prediction System (NOGAPS) or from the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS). The lateral open boundary conditions are either taken from a global ONFS or from a higher resolution regional ONFS if one is available.

As part of this project, The NRL ONFS will be implemented for the coastal waters of Mississippi, Louisiana and part of Texas (MS-LA-TX Coastal ocean model). The area of coverage extends from 95.5° to 88.2°W longitude and from 27.0° to 30.5°N latitude as indicated by the red grid of Figure 1. The ocean model is operated with a 1.9-km resolution grid and coupled to the NRL Intra-Americas Sea Ocean Nowcast/Forecast System (indicated in part by the blue grid in Figure 1). The vertical grid consists of 36 layers with 19 sigma layers from the surface down to 138 m and fixed-depth layers from 138 m to the bottom.

Model bathymetry is first interpolated from the NRL DBDB2, a global 2-min ocean bathymetry data base (http://www7320.nrlssc.navy.mil/DBDB2_WWW/), and combined with NOAA NGDC (National Geophysical Data Center) 15-minute grid data. The model land-sea boundary is adjusted based on the coastline from the Generic Mapping Tools (GMT) software. More than half million of the sounding data are then assimilated to form the model bathymetry. Figure 4 shows the distribution of the sounding data from which bathymetry will be determined.

The MS-LA-TX coastal model will provide nowcast and forecast outputs of sea level variation, 3-D ocean currents, temperature and salinity. The model is driven by winds, heat fluxes, solar radiation, and air pressure. The model is initialized with temperature, salinity, sea surface elevation, and current interpolated from the IASNFS prediction. The IASNFS also provides the open boundary conditions (BC) for the model. Atmospheric forcing consists of 3-hourly fields of sea level air pressure, wind stress, solar radiation, and surface heat flux from the COAMPS Central America analysis/forecast model. The meteorological fields are interpolated to the ocean model grids using a cubic spline. Data forcing for the model boundary conditions will use some

NASA products (e.g., SSH from Jason, SST from MODIS). The coastal circulation model will be nested within the larger Gulf of Mexico model that uses the SSH data from Jason and other satellites such as GFO (Navy), TOPEX and ENVISAT. Real-time nowcasts and forecasts will be conducted daily.

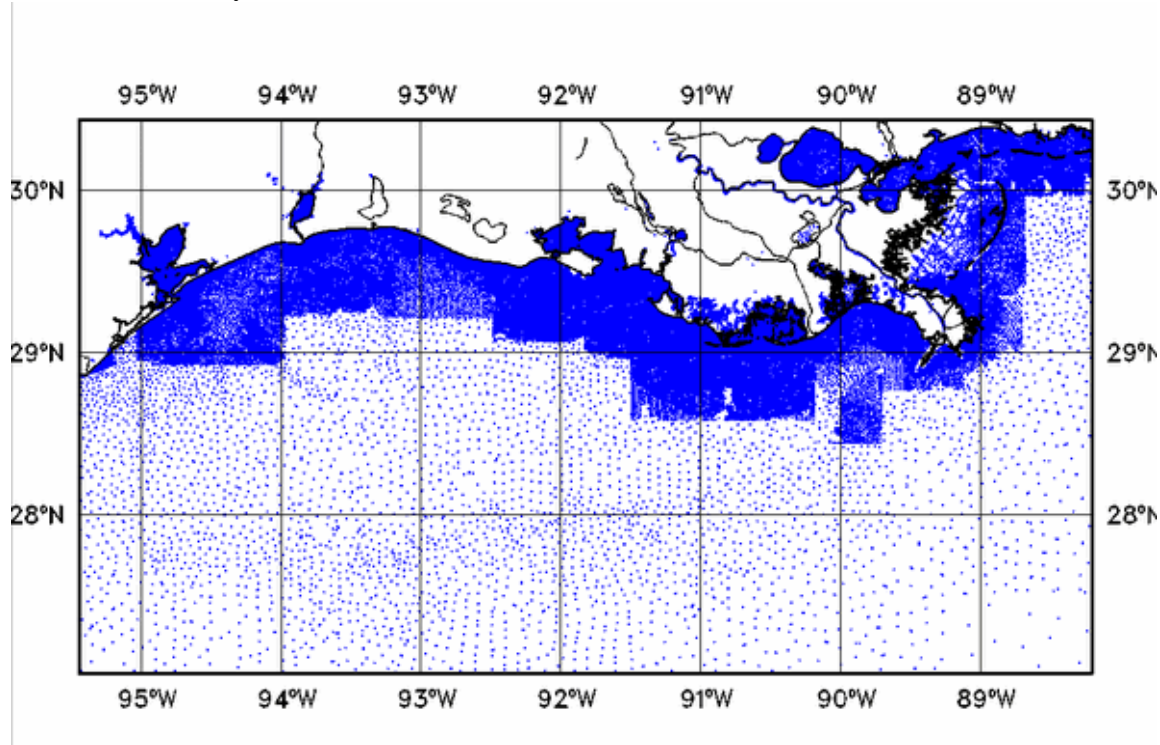


Figure 4. Sounding data for the coastal region for bathymetry data that will be used in the coastal model.

A web based interface linked to the WAVCIS website will be developed that will incorporate GIS and database of assimilated NASA Earth Science data and models that will be conducive to decision making. The benefits of web-based accessibility include among others the availability of information to anyone with computer and Internet access. A web site design has been initiated that will provide inter-linked access to NASA and model products and WAVCIS system. A GIS based database of images and information layers will be provided through the web site. This feature is expected to improve the effectiveness of the DSS through its capability for inventory storage, display, query, and overlays and its ability to improve the information content to the user not familiar with the complexities of the scientific data. We have acquired commercial GIS software such as ERDAS Imagine and ARC-GIS for use in the project.

3. Implementation plan of how the proposed work will be implemented into the DSS

The following NASA remote sensing products will be acquired from NASA DAAC and after processing will be assimilated and served to the users through a web server (WIPE, from Actgate) and through an internet web server (Apache server) on a Linux based system:

MODIS 1 km products (SST, Chlorophyll, TSM or Total Suspended Matter, CDOM+Detrital absorption, CDOM absorption from regional algorithm)

QuikSCAT wind products (speed and direction at 25 km resolution)

QuikSCAT wind products (new wind speed/direction product at 12.5 km resolution generated by DAAC)

Jason SSH products (SSH anomalies)

Jason Wind Speed and Wave height products (new product generated by DAAC)

MODIS 250 m Direct Broadcast reflectance data (from LSU's Earth Scan Laboratory)

MODIS 250 m reflectance data from DAAC

The WIPE Server has been designed to be optimized for decision support. We plan to use the WIPE server to provide user access to NASA remote sensing products and the NRL MS-LA-TX coastal model outputs. We plan to use commercial software programs such as IDL, ENVI (from RSI systems) for processing the remote sensing data. Web-based accessibility is conducive to decision making and we are developing a web site that will provide the information with anyone with computer and Internet access. The web site will provide inter-linked access to NASA data and products, model outputs, and WAVCIS.

Re-evaluation: A critical re-evaluation of NASA products for assimilation into the enhanced DSS is ongoing. We will re-examine the NASA data products for: sources, latency, consistency, enhancements, spatial and temporal resolution, and data access. For example, we have examined the new 12.5 km QuikSCAT wind speed/direction product from DAAC and determined from a preliminary evaluation that this wind product would be more useful for assimilation into the enhanced DSS.

Verification and Validation (V&V or assessment) of NASA data and satellite products has been detailed in the project proposal. Statistical Analyses to support performance measures will be conducted in consultation with an experimental statistician.

The NRL ocean nowcast/forecast system (ONFS) will be implemented for the Mississippi, Louisiana and part of Texas coastal waters. Several years of hindcast data will be used for evaluation of model outputs. Model predictions will be evaluated and sensibility of the model prediction to various forcing and data assimilation to improve model prediction will be conducted. The ocean nowcast/forecast system will then be integrated into the enhanced DSS.

A GIS based database of images and information layers will implemented in this project. An example of Landsat images in a GIS format that could be assimilated into the enhanced DSS and be made available to end users. The Landsat images shown in Figure 5 are of the Louisiana coast taken on 21 September 2005 and 7 October 2005 showing the effects of flooding along the Louisiana coast following Hurricane Rita.

Benchmarking the DSS: The benchmarking activities will be used to evaluate the DSS performance before and after the assimilation of NASA products, data and models into the enhanced DSS. We will address issues such as usability, network bottlenecks, usefulness, frequency of use, forecast accuracy in consultation with partners in benchmarking the DSS. The impact and outcomes from the assimilation of NASA products and model outputs into the DSS will be documents as part of the project.



Figure 5. Processed Landsat images (21 September and 7 October 2005) showing the effects of flooding along the Louisiana coast following Hurricane Rita in September of 2005. Such images would be incorporated in a GIS based database that would be available to the user community.

3a. Detail Project plan/schedule

Year 1

- Ongoing discussion with main users (MMS and LDNR project advisors)
- Set up a high performance Quad Core Linux computer and install software and servers (e.g., WIPE server).
- Install additional hardware for data ingest and processing of NASA products
- Set up database for the NASA data and products for the MS-LA-TX coastal waters
- critical re-evaluation of NASA products for assimilation into the enhanced DSS
- develop web site for the enhanced DSS and linked to the WAVCIS site
- Develop programs for processing and analysis of NASA data and products
- Determine formatting and data structure issues
- Initiate V&V for NASA products of Northern Gulf of Mexico
- initiate studies related to performance measures using statistical analyses
- Initiate creation of image library of NASA products of coastal MS-LA-TX coast
- Initiate GIS development
- Implement the NRL ocean nowcast/forecast system (ONFS) the Mississippi, Louisiana and part of Texas coastal waters. Several years of hindcast will be conducted and provided to project PIs for evaluation.
- Conference presentations
- Quarterly reports and annual report

Year 2

- PI, co-PIs and project advisor meeting to examine requirements and methods being addressed
- Continue project activities related to assessment of NASA data and products into the DSS
- Continue web site and server (e.g., WIPE) development work
- Field data acquisition and use for assessment and validation of NASA products
- Continue V&V activities for assessment of NASA products into the enhanced DSS
- Continue with creation of image library of NASA products of coastal MS-LA-TX coast
- Initial verification of products to be completed
- conduct performance measures using statistical analyses

- Collaborate with project PIs to evaluate model predictions and conduct studies on the sensibility of the model prediction to various forcing and data assimilation to improve model prediction
- Demonstrate optimal Internet access capability for NASA results
- Continue GIS development and implementation into the DSS
- Conference presentations and publication in refereed journals
- Quarterly reports and Year 2 Verification and Validation report

Year 3

- PI, co-PIs and end user meeting to examine requirements and methods being addressed
- Continue work related to V&V activities
- Continue with creation of image library of NASA products of coastal MS-LA-TX coast
- Automate remote sensing and model data flow to the enhanced DSS
- Integrate the ocean nowcast/forecast system into the DSS
- Refinement of the enhanced DSS based on partner inputs
- Initiate benchmarking activities of required products
- Quarterly reports
- Benchmarking report at the end of the project (Comparison of DSS with assimilated NASA and model measurements compared to the baseline DSS. It will also describe how the DSS is working for the institution and the end user)
- Conference presentations and publication in refereed journals

4. Feedback mechanism and end users

This project plans to enhance the current WAVCIS DSS with NASA satellite products, coastal models and to extend the DSS capability to a larger region in the northern Gulf of Mexico to include the Mississippi, Louisiana and parts of Texas coastal region. Specifically, the enhanced DSS will support users such as MMS and LDNR. MMS provides policy direction relative to the development of all marine mineral resources located in Federal waters and balancing orderly energy resource development with the protection of human, marine and coastal environments. MMS uses descriptive, experimental, monitoring, or synthesized information to provide decisions related to offshore oil and gas activities and the use of offshore sand resources for coastal restoration. In coastal and offshore waters of the northern Gulf of Mexico (specifically along the coastal states of Mississippi, Louisiana, and Texas) activities related to oil and gas production and use of Federal borrow (sand) resources for coastal restoration are well-developed and increasing. LDNR advisors have indicated that the enhanced DSS comprising of NASA remote sensing products and model outputs could be used in decision making related to coastal restoration projects and diversion flow control. Instances include decision on control of diversion flows (for coastal restoration) based on DSS outputs of remotely sensed suspended matter and plume indicators. Three-dimensional model outputs (e.g. salinity, currents) for example could provide boundary conditions to smaller models being used to model the effects of planned diversion projects, an important decision in terms of resource allocation.

Recently, PIs working on an MMS and the LDNR funded project titled “Environmental investigations of the long-term use of Ship shoal sand resources for large-scale beach and coastal

restoration in Louisiana” have requested the use of this NASA funded DSS enhancement outputs to be used in their environmental impact studies of sand mining on larval fish transport. We plan to continue working with the end users and project advisors from MMS and LDNR to further assess their requirements and optimize the DSS based on their inputs. We plan to assess risks of various enhanced products (e.g., inadequate accuracy of remote sensing products, untimely receipt of remote sensing data) during the benchmarking process. In addition we will obtain feedback from users who request and/or use the data and other information from the website. We will also identify classes of users (researchers, MMS, LDNR, public) who obtain products and services from the project. This should help us quantify the societal benefits of the DSS.